Human Dimension Challenges to the Maintenance of Local Area Awareness Using a 360 Degree Indirect Vision System

Jason S. Metcalfe, Ph.D., Keryl A. Cosenzo, Ph.D., Tony Johnson, Bradley Brumm, Christopher Manteuffel, A. William Evans, Ph.D., and Terrance Tierney

TARDEC ARL

GVSETS

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **12 AUG 2010**	2. REPORT TYPE **Briefing Charts**	3. DATES COVERED **08-02-2010 to 23-07-2010**

4. TITLE AND SUBTITLE **Human Dimension Challenges to the Maintenance of Local Area Awareness Using a 360 Degree Indirect Vision System**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Jason Metcalfe; Keryl Cosenzo; Tony Johnson; Bradley Brumm; Christopher Manteuffel**	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **DCS CORP,7400 Miller Dr,Warren,Mi,48397-5000**	8. PERFORMING ORGANIZATION REPORT NUMBER **; #21125**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000**	10. SPONSOR/MONITOR'S ACRONYM(S) **TARDEC** 11. SPONSOR/MONITOR'S REPORT NUMBER(S) **#21125**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
For 2010 GROUND VEHICLE SYSTEMS ENGINEERING AND TECHNOLOGY SYMPOSIUM (GVSETS) AUGUST 17-19

14. ABSTRACT
briefing charts

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Public Release**	**26**	

Acknowledgements

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TARDEC

- Bradley Brumm*
- Dina Kahn
- Jennifer Miller
- Larry Sieh
- Terrance Tierney*

ARL

- Keryl A. Cosenzo, Ph.D.*
- A. William Evans, Ph.D.*
- Theodric Feng

DCS

- Jason Cox
- Stephen Gordon, Ph.D.
- Matthew Jaswa
- Tony Johnson*
- Christopher Manteuffel*
- Jason Metcalfe, Ph.D.*
- Xung Nahm
- Steve Scheiner
- Joshua Sidman
- Jae Song

* co-author on current presentation

Presentation Outline

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- Results
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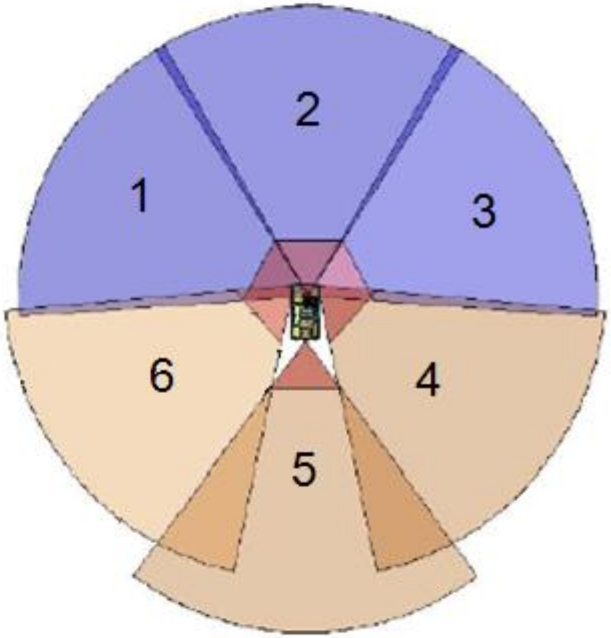


Introduction


Photos from: http://search.ahp.us.army.mil/search/images/

- Urbanization of Conflict and Situational Awareness
  - Modern conflicts are increasingly being carried out on an urban stage
  - This urbanization imposes important changes in battlefield constraints:
    - Due to the presence of many people including combatants and noncombatants
    - Due to exponential additions to complexity imposed by a dense, diverse, and irregular array of multidimensional structures
  - These and other factors dramatically increase the cost of failing to maintain Situational Awareness (SA) on the battlefield

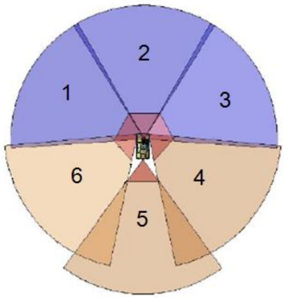
Introduction

- How the Army is Responding
  - Increasingly conducting operations from within “buttoned-up” (closed-hatch) vehicles
  - Maturing and developing advanced indirect-vision systems for enhancing SA including
    - real-time, full-spectrum (360°/90°) visualization options
    - computational enhancements to data visualization

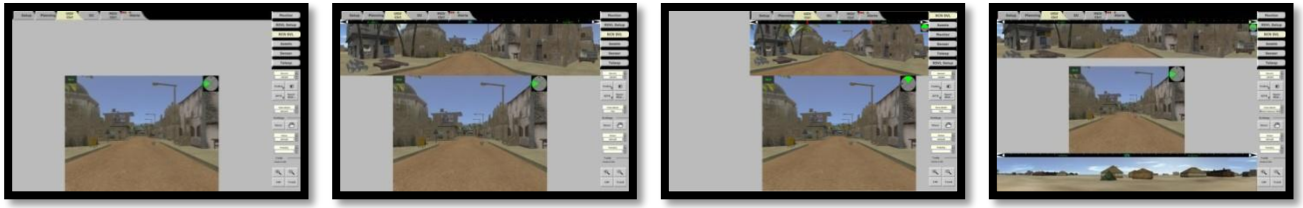
- Human Factors Challenges to 360° Local Area Awareness (LAA)
  - Humans are limited in visual processing in terms of:
    - the distribution of objects throughout space
    - the number of items that can be held in working memory
    - the temporal dynamics for processing new information
  - Cognitive biases further impact the ability to form SA:
    - “cognitive tunneling”
    - “out of the loop syndrome”

- Experiment Overview: Objectives

Our experiment examined the factors that can influence performance of a threat detection and identification task using a simulated system of sensors providing 360° LAA.

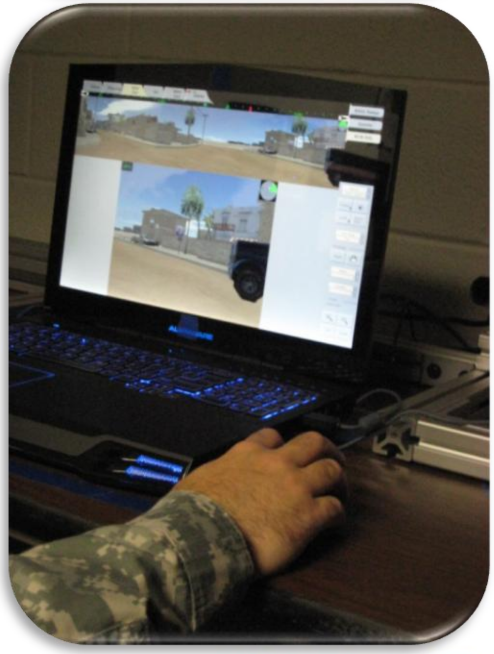


- Four display configurations, representing variations of two 360° Indirect-Vision Display (IVD) concepts were assessed as U.S. Soldiers and civilians performed threat detection using a display representing the view from within a simulated moving vehicle during execution of a presence patrol.



- Beyond examination of display configurations, the dynamics and composition of the simulated environment were structured to allow for statistical investigation of human perceptual-cognitive issues related to threat detection performance.

- Experiment Overview: Design
  - N = 17 (7 Soldiers, 10 civilians)
  - Major Manipulation
    - One explicit independent variable, **display configuration**, with four levels.
    - Each configuration was assessed within one of four unique operational scenarios (counter-balanced)
  - Within-scenario manipulations (covariates):
    - Threat Type (Armed Human, Unarmed Human, IED)
    - Threat Range
    - Threat Location
    - Threat Mobility
    - Vehicle Mobility
    - Threat Reporting Criteria (for unarmed humans) based on environment
    - Inter-Threat Interval



Method

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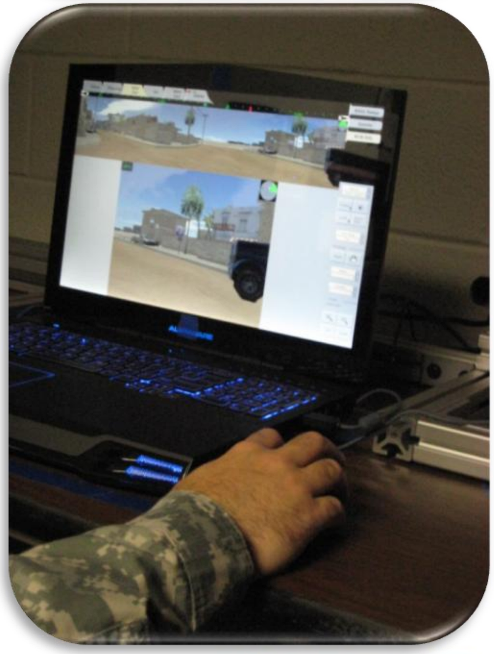
- ## Experiment Overview: Tasks

  Assume role of MGV Commander conducting a presence patrol in an urban environment.

  - Identify threats while stationary and on-the-move
    - Sector of observation: entire 360° around vehicle
    - Range of observation: extends 200 meters from vehicle
  - Send digital “SPOT” report – custom report created for data collection purposes
    - Activate SPOT/BDA report upon detection
    - Select Threat Location (Vehicle-relative clock position 1-12)
    - Select Threat Type
  - Listen for audio alerts regarding the following events (no acknowledgement was required):
    - Vehicle Halt / Resume
    - Entering / Leaving “free fire zone”
    - High value targets



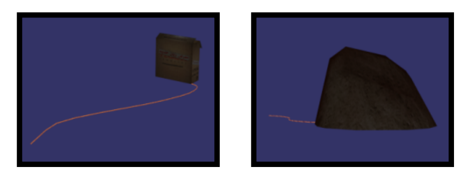
Method

- Scenario Composition
  - Design & implementation guidance
    - SME Input
    - Independent research
  - 38 Threats per scenario
    - Scripted threats were intermingled with planted decoys
    - Threats included: 17 Armed Humans, 13 Unarmed Humans, and 8 IED’s
  - Mission Context Manipulation
    - City vs. Outskirts
      - Outskirts = “free-fire zone” and thus all humans, armed or unarmed, were report-worthy
    - 19 targets in each environment

Unarmed humans in native dress

Armed humans in native dress

IED’s (indicated by fuse)



Decoy IED’s

Method

Label	Description	# per Scenario
Crowd	Group of 10+ non-threatening humans	1
Hidden IED	Various objects with large wires (fuses), included in both urban core and outskirts	8
Decoy IED	Various objects without apparent fuses	~50
High Value Target (HVT)	Targets that were not threatening until radio communiqué warning of danger	3
Vehicle Stop	Instances were vehicle motion pauses	4
Suspicious Behavior	Unarmed humans behaving in threatening manner	5
Ambush	Group of humans that remained concealed until vehicle was near; no engagement	2
Cut off	Blockage of nearest escape or of main route	2
Armed Human	Humans visibly carrying weapons	17
Unarmed Human I	Unarmed humans considered threats	13
Unarmed Human II	Unarmed humans not considered threats	~10-20

- Display Concepts and Configurations

Sensor Display Portal

- 64° × 48° Field of View (FOV)
- No continuous pan/zoom capabilities
- 6 selectable views (1 per simulated camera)
- Views controlled by mouse clicks on an embedded graphic (top right corner)

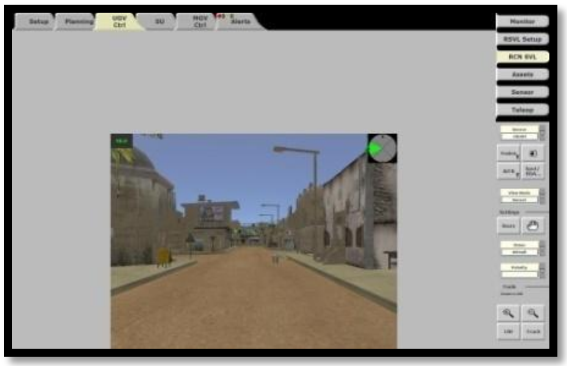
Banner

- 180° Horizontal Field of View (hFOV)
- No pan/zoom capabilities
- Single fixed view: either front or rear 180°
- Single view represents a "stitched" composition of three cameras

Method

- Display Concepts and Configurations

A

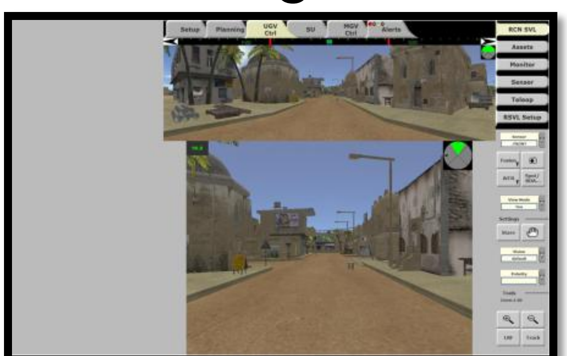


1024 × 768 Sensor
No Banner

B

1024 x 768 Sensor
1728 x 369 Banner

C



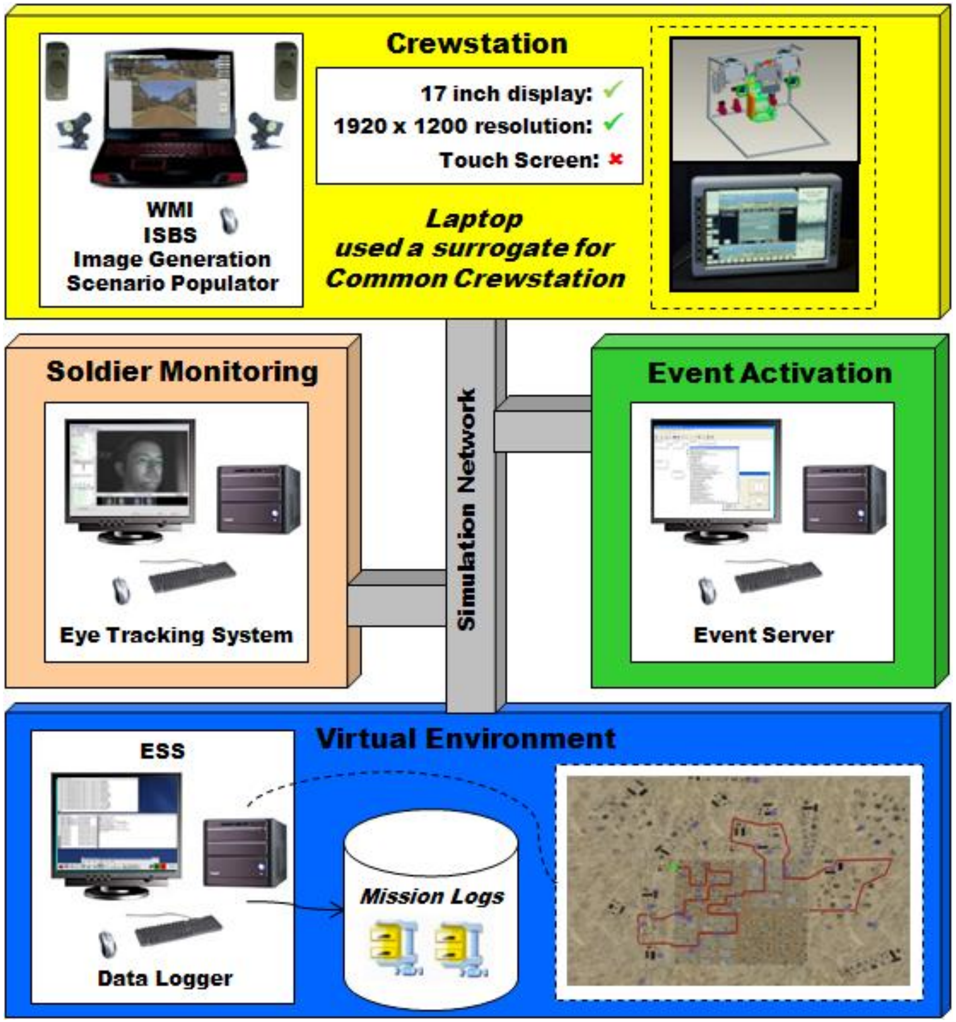
1024 x 768 Sensor
1248 x 369 Banner

D

512 x 384 Sensor
1728 x 369 Banner
- 1 front 180
- 1 rear 180
- Rear 180 was Lt-Rt reversed

- Simulation Environment

- **WMI**
  - Sensor Displays
  - Sensor Controls
  - SPOT Report
- **Image Generation**
  - Entity / Terrain Rendering
- **ISBS**
  - Route Conformance
- **Scenario Populator**
  - Dismount Mobility
  - Env. Vehicle Mobility
  - Crowd Behaviors
  - Static Entities
- **Event Server**
  - Trip Line Activation
  - Play Audio Files
  - Prompt Scenario Populator
- **ESS**
  - Vehicle Mobility Model
  - Sensor Model
  - LOS Checks
- **Data Logger**
  - Log File Creation
  - DIS Recorder
  - Entity Monitoring
- **Data Extraction**
  - Data Archive Generation

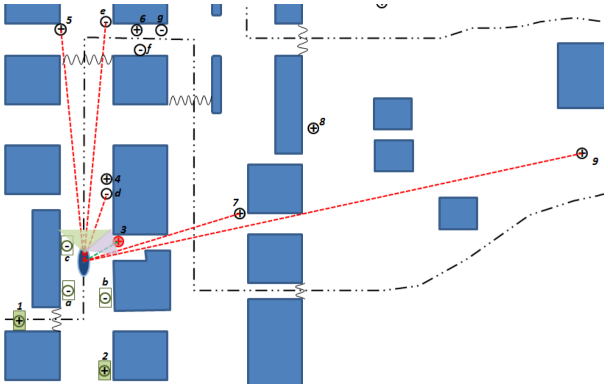


- Data Reduction and Analysis
  - All measures calculated from a reduced, collated, and time-synchronized set of variables extracted from the raw data set.
    - All data processing and synchronization were handled by a custom written program called the Data Analysis and Reduction Tool.
      - Beginning with merging all data logs into a single binary format, all events and entity characteristics were codified and subsequently collated using a common time-stamp.
    - Using the collated and merged data, custom algorithms were created to assess each SA report against the target LOS events.
      - For cases in which the LOS tool failed to provide accurate target information, manual corrections were applied.

Objective measures: Data for missions (1-68)

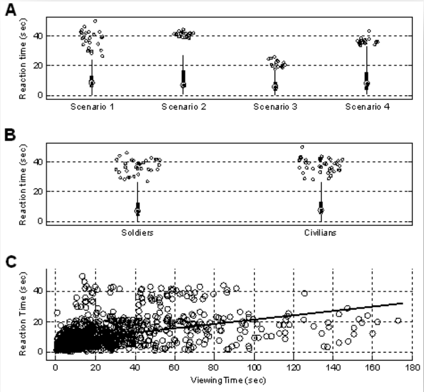
Name	Size	Type	Date Modified
IMOPATX01.M01.P01.S1.C2.R1	9,497 KB	Compressed (zipped) Folder	11/9/2009 12:42 PM
IMOPATX01.M02.P01.S2.C3.R2	6,280 KB	Compressed (zipped) Folder	11/9/2009 1:55 PM
IMOPATX01.M03.P01.S3.C1.R3	7,424 KB	Compressed (zipped) Folder	11/9/2009 2:03 PM

Name	Type	Size	Date
ESPDURecord	BIN File	10,675 KB	11/9/2009 11:44 AM
CrewstationLog	Microsoft Office Excel Comma Separated Values File	9 KB	11/9/2009 11:44 AM
SensorViewBBLog	Microsoft Office Excel Comma Separated Values File	748 KB	11/9/2009 2:35 PM
SensorViewFCLog	Microsoft Office Excel Comma Separated Values File	433 KB	11/9/2009 2:34 PM
SensorViewFLLog	Microsoft Office Excel Comma Separated Values File	147 KB	11/9/2009 2:36 PM
SensorViewFRLog	Microsoft Office Excel Comma Separated Values File	158 KB	11/9/2009 2:28 PM
SensorViewRCLog	Microsoft Office Excel Comma Separated Values File	483 KB	11/9/2009 2:31 PM
SensorViewRLLog	Microsoft Office Excel Comma Separated Values File	224 KB	11/9/2009 2:34 PM
SensorViewRRLog	Microsoft Office Excel Comma Separated Values File	184 KB	11/9/2009 2:27 PM
SensorViewTBLog	Microsoft Office Excel Comma Separated Values File	693 KB	11/9/2009 2:35 PM
SmartEyeDataLog	Microsoft Office Excel Comma Separated Values File	35,124 KB	11/9/2009 11:44 AM
TripLineLog	Microsoft Office Excel Comma Separated Values File	1 KB	11/9/2009 11:44 AM
VehicleStatusLog	Microsoft Office Excel Comma Separated Values File	12,676 KB	11/9/2009 11:44 AM



Method

- Data Reduction and Analysis
  - Task Performance Measures
    - Threat detection rate
    - Response time
    - Report accuracy
    - Sensor portal usage
  - Physiological Measures
    - Gaze point tracking
    - Nearest-neighbor index
  - Subjective Questionnaire Responses
    - NASA Task Load Index (NASA-TLX)
    - Interface usability
    - Exit interview



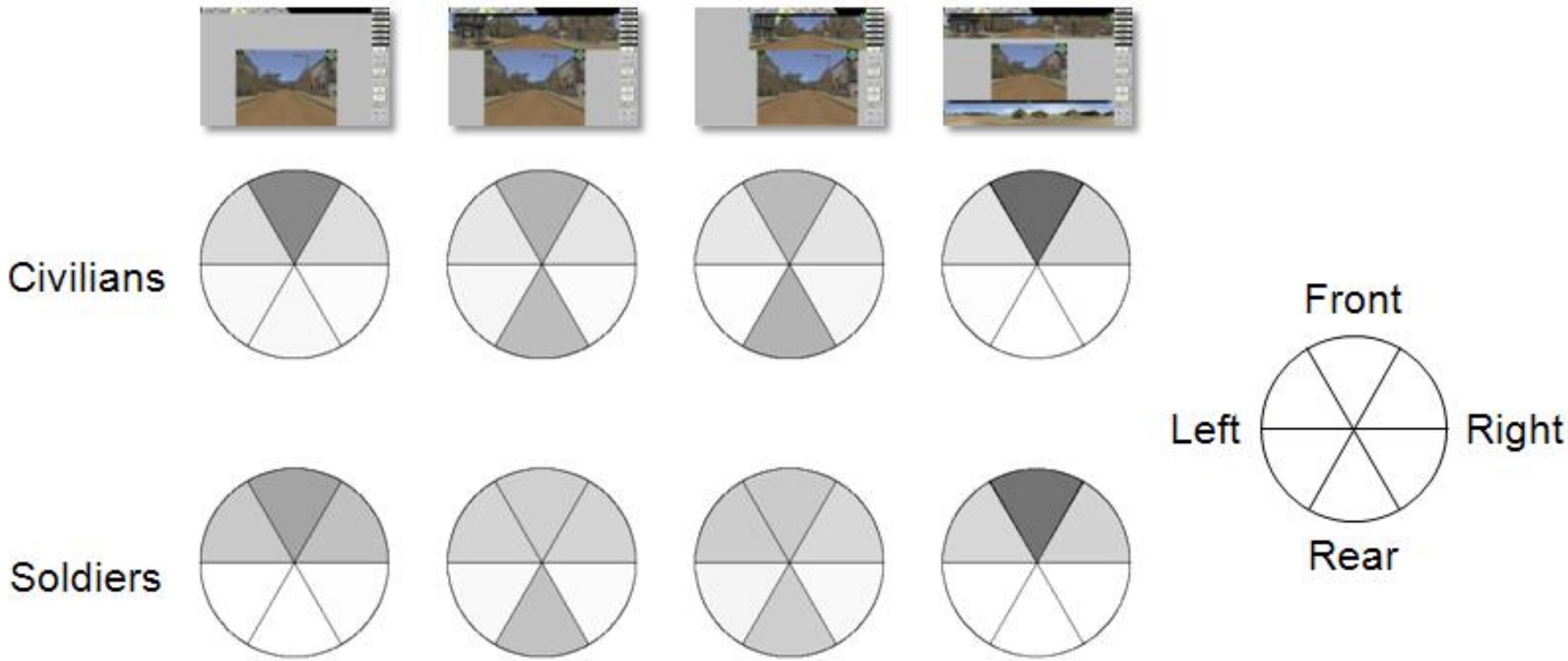
Parameter	df_{reg}	$F(df_{reg}, 2499)$	p
Scenario	3	2.0495	0.1049
Participant type	12	5.8368	0.0000
Condition	24	7.6205	0.0000
Target type	18	5.8685	0.0000
Location	11	10.3761	0.0000
Vehicle Mobility	10	3.0226	0.0008
Target Mobility	8	1.5188	0.1453
Min range after onset	9	45.4816	0.0000
Inter-threat Interval	7	3.7049	0.0005
Viewing Time	8	39.8973	0.0000
Participant type x condition	3	2.2665	0.0788
Participant type x target type	2	2.9305	0.0536
Participant type x location	1	1.5531	0.2128
Participant type x vehicle mobility	1	0.0003	0.9855
Participant type x target mobility	1	0.0004	0.9843
Participant type x min range	1	0.2169	0.6414
Participant type x inter threat interval	1	0.0692	0.7925
Participant type x viewing time	1	0.0770	0.7814
Condition x location	3	8.8535	0.0000
Condition x vehicle mobility	3	0.3976	0.7548
Condition x target mobility	3	2.0875	0.0998
Condition x min range	3	1.9371	0.1214
Condition x inter-threat interval	3	0.4231	0.7364
Condition x viewing time	3	6.3462	0.0003
Target type x location	2	14.6222	0.0000
Target type x vehicle mobility	2	3.1169	0.0445
Target type x target mobility	2	0.4936	0.6105
Target type x min range	2	12.9712	0.0000
Target type x onset delta	2	0.8896	0.4109
Target type x viewing time	2	2.3579	0.0948
Location x vehicle mobility	1	7.4223	0.0065
Location x target mobility	1	32.6323	0.0000
Location x min range	1	1.7350	0.1879
Location x viewing time	1	30.2822	0.0000
Vehicle mobility x target mobility	1	0.0000	1.0000
Vehicle mobility x min range	1	4.7783	0.0289

Parameter	Wald χ^2	df	P
Condition(participant)	20.085	18	0.328
Target type(participant)	70.785	13	0.000
Location(participant)	256.243	8	0.000
Vehicle Mobility (participant)	46.232	17	0.000
Target Mobility(participant)	66.631	14	0.000
Min range after onset (participant)	36.551	17	0.004
Inter-threat Interval (participant)	37.389	17	0.003
Viewing Time(participant)	102.391	17	0.000
Condition x location(participant)	1206.501	46	0.000
Target type x location(participant)	100.095	15	0.000
Target type x min range(participant)	51.764	34	0.026
Location x target mobility(participant)	71.540	14	0.000
Location x viewing time(participant)	85.474	17	0.000

  - Data Analysis and Statistical Processing were handled separately
    - Analysis methods depended on nature of variable being assessed
    - Primary methods: logistic regression and linear mixed-model regression

Results

- Active Scanning

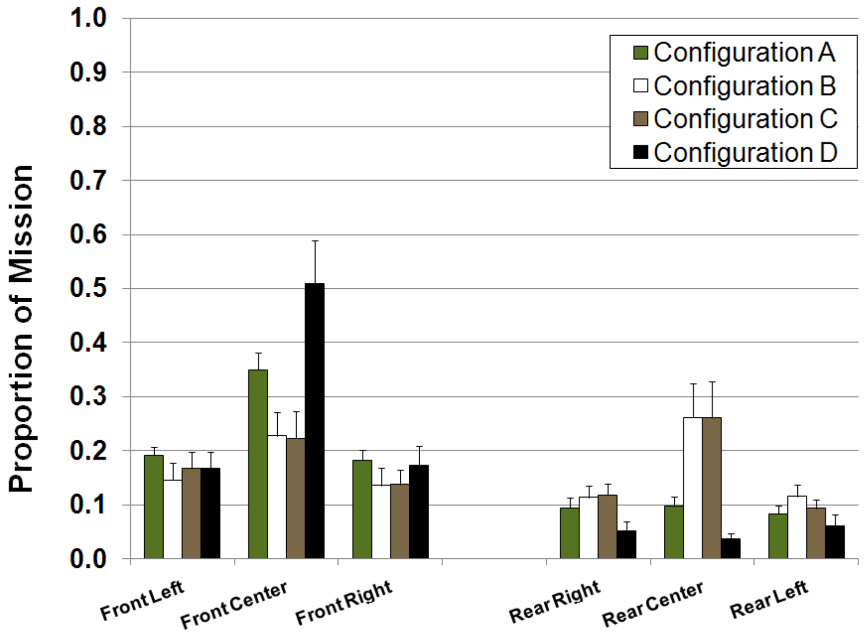


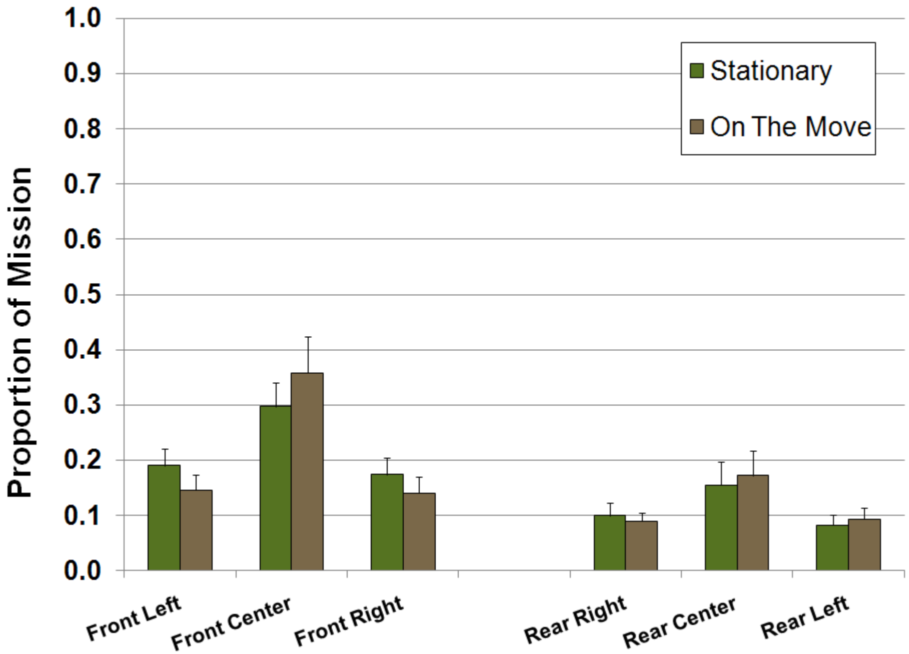
Qualitatively, all participants (Soldiers and civilians) tended to disproportionately orient on the forward view, with generalized a bias towards orienting on the central position.

Tendency was observed less strongly when using configurations B and C

Results

- Active Scanning





Statistically, this pattern of results appeared as two significant interactions:

- Sensor View × Display Configuration ($F_{15, 815} = 10.09$, $p < 0.001$)
  - Validates qualitative observations from last slide
- Sensor View × Vehicle Mobility ($F_{5, 815} = 10.33$, $p < 0.001$)
  - Indicates that front-center bias grew stronger when vehicle was moving

Results

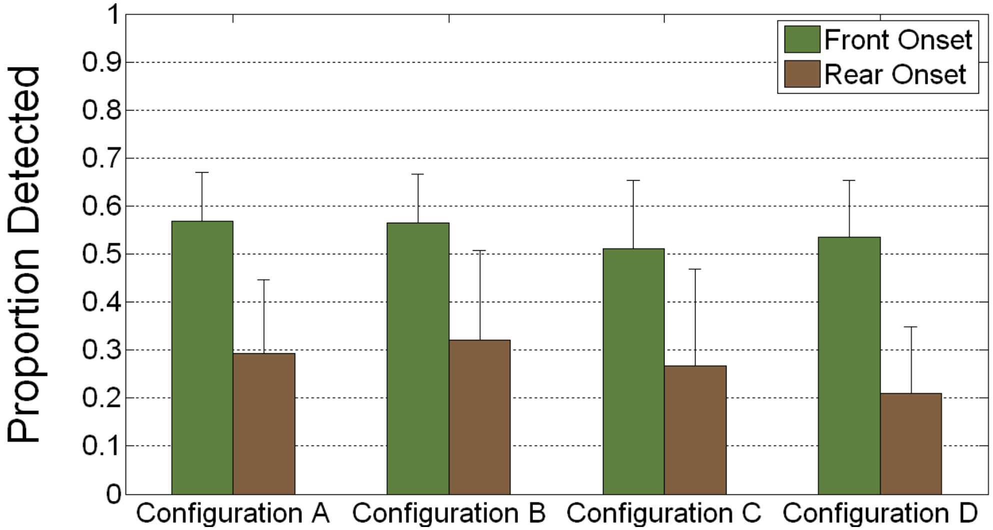
- Active Scanning

Configuration	View Changes (changes per mission)	View Change Rate (changes per minute)
A	381.5	28.2
B	171.4	12.6
C	189.2	13.8
D	131.0	9.6

Participants had to perform nearly twice as much physical work when using Configuration A

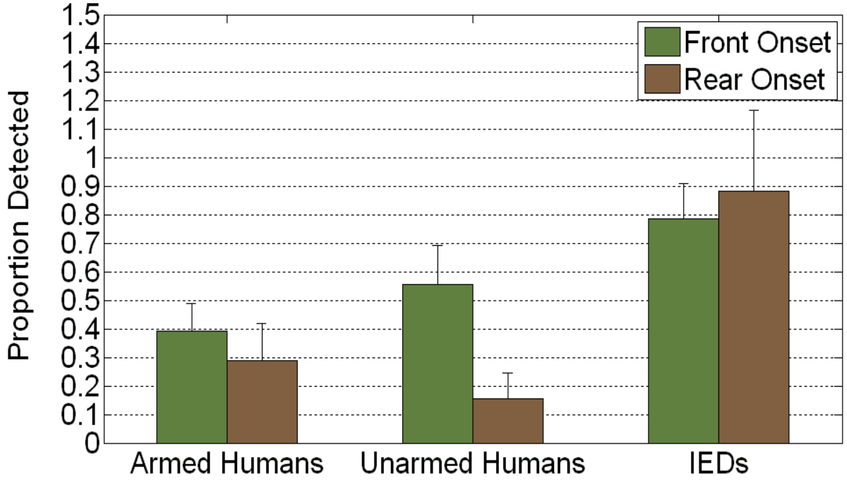
- Scanning → Threat Detection (?)

A significant Configuration × Location interaction ($F_{3,\ 2538} = 12.99$, $p < 0.001$) points to a possible, though not dramatic, advantage for Configuration B



Results

- Threat Detection Performance

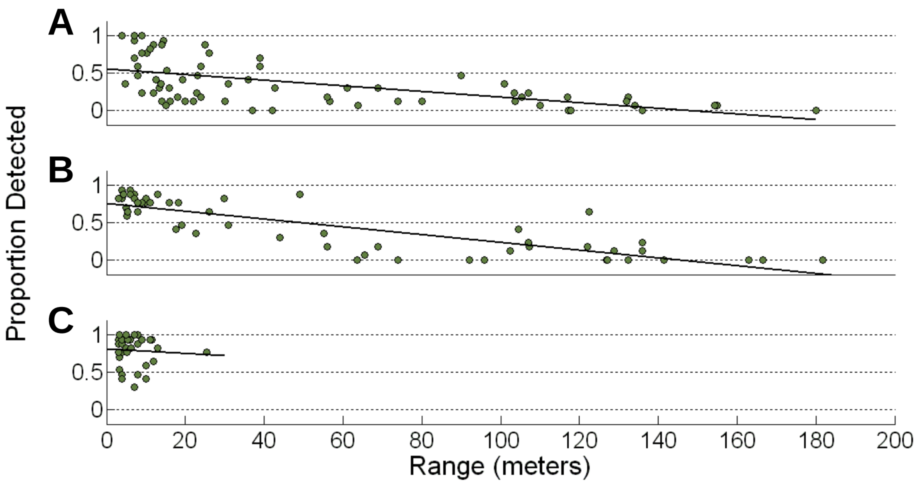


Target Type x Location interaction

- Wald $\chi^2_{15} = 100.10$, $p < 0.001$
- IEDs were always detected well
- Detection rates were below 50% for armed humans
- Detection rate for unarmed humans was higher when presented in the front

Target Type x Range interaction

- Wald $\chi^2_{34} = 51.76$, $p < 0.03$
- Indicates different slope across Range for each target type
- May reflect differences between Armed and Unarmed Humans at short ranges (< 25 m)



A) Armed Humans; **B)** Unarmed Humans; **C)** IEDs

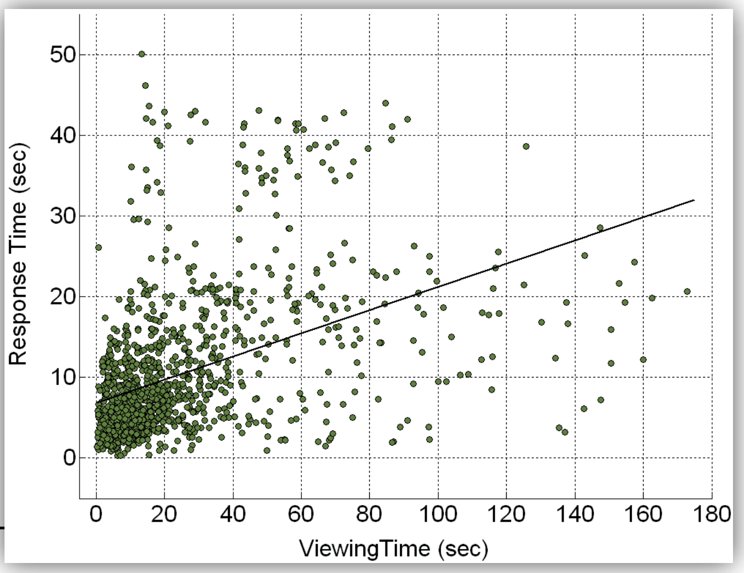
Points to a strong influence of perceptual factors on threat detection

Results

- Response Time vs. Report Accuracy

Location × Range Interaction
($F_{2,1213} = 11.878$, $p < 0.001$)

Location	< 50m	50 – 100m	> 100 m
Front	5.99 (0.15)	14.67 (0.58)	20.43 (0.67)
Rear	5.79 (0.38)	7.17 (2.01)	9.43 (1.85)



Vehicle Mobility × Range Interaction
($F_{2,1213} = 5.21$, $p < 0.01$)

Vehicle Mobility	< 50m	50 – 100m	> 100 m
Stationary	4.05(.46)	7.65(.89)	8.16(.50)
Moving	6.10(.26)	14.41(.42)	21.41(.48)

A general response pattern was indicated wherein participants appeared to scale their response timing to how much viewing time was available

Results

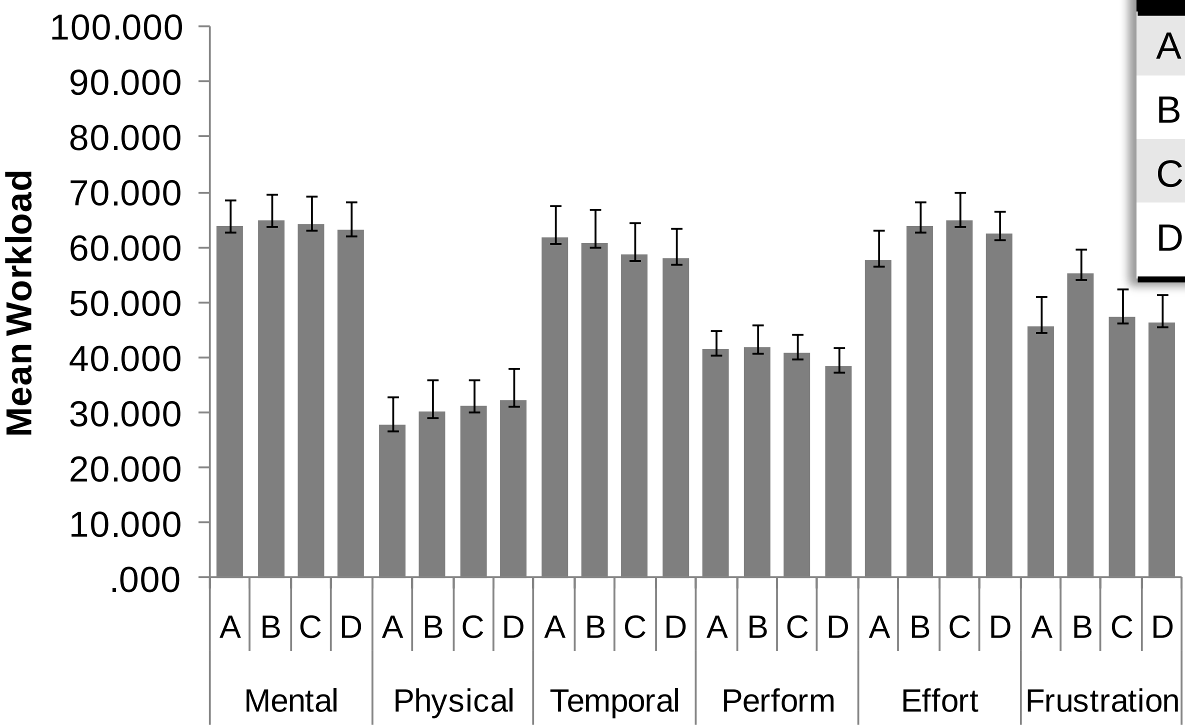
- Response Time vs. Report Accuracy

Target Range	Armed Humans	Unarmed Humans	IEDS
< 50m	88.0 (1.61)	88.7 (2.63)	85.4 (1.51)
50-100 m	72.9 (2.69)	85.1 (2.90)	87.4 (2.86)
> 100 m	59.2 (3.26)	85.5 (5.58)	94.4 (4.31)

Accuracy values were fairly high, and only showed marked declines for Armed Human threats presented at greater distances from the vehicle (where Armed Humans were more easily confused for Unarmed Humans)

Results

- Subjective Questionnaires: Workload



Configuration	Overall Workload
A	56.666 (3.83)
B	60.000 (3.07)
C	59.509 (3.54)
D	57.196 (3.22)

Subject workload assessments were insensitive to variation due to Display Configuration; Average rating indicated that the task was not overwhelming

Results

- Subjective Questionnaires: Usability and Exit Interviews
  - Participants ranked the configurations in order of preferred use, with 1 being the most preferred and 4 being the least.
  - The resulting rank order was:

    Configuration D (1.59), Configuration B (1.65), Configuration C (2.88), Configuration A (3.88).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	% All	% Sld
Banner preferred	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100	100
Wants zoom		x		x	x				x		x	x			x		x	47.1	71.4
SA report problem	x			x		x	x	x							x	x	x	47.1	42.9
Sensor control problem	x		x					x	x					x				29.4	28.6
Wants continuous panning		x								x		x				x	x	29.4	14.3
Sensor aimed at rear			x			x		x			x				x			29.4	14.3
Wants interactive targeting						x	x	x						x				23.5	14.3
Overwhelmed by information						x					x		x			x	x	29.4	14.3

All participants preferred a banner solution and a majority wanted a zoom capability. Few participants felt a need for improvements to augment looks to the rear of the vehicle and few felt overwhelmed by the task.

Discussion

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- The most striking observation: emergence of a front-center bias, discussed elsewhere as “the keyhole effect” or cognitive tunneling.
  - Despite clear instructions that participants were responsible for scanning the full environment, they tended to focus on the central aspect of their forward view.
  - This trend appeared particularly strongly when using configuration A, which provided no alternatives for simultaneously viewing both the front and the rear.

- Although there was a clear difference in the use of the different display configurations, it was not manifest in a strong independent influence of display configuration on performance.
  - Evidence indicated a weak facilitation of performance that depended on whether front and rear-facing visuals could be viewed simultaneously
    - Not observed with configuration D, but there were additional cognitive factors potentially affecting the ability to use both front and rear-facing banners simultaneously
  - Otherwise, it seemed that the primary factors influencing performance were those associated with human perception and cognition.

Discussion

- Some results indicated target salience as a factor and thus, future study and technology assessments involving explicit manipulations of salience seem warranted.
  - If salience is shown to be a critical factor in threat detection and identification performance, then additional mitigations possibly involving real-time image processing may be required for enhancement of LAA in operational contexts.

- Results also pointed towards a need to assist the Soldiers in ways that offset their natural cognitive and perceptual tendencies.
  - Technical solutions, such as better optics or implementation of zoom may suffice to account for the range-based detriment
  - However, accounting for the "tunneling" bias may require additional types of technologies
    - e.g.: intelligent systems that detect, in real time, where the Soldiers are looking and then cueing examination of neglected areas of the operational environment.

Conclusions

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- Manipulations of display configurations may be able to mitigate the impact of natural cognitive and perceptual tendencies of the participants; however, the mitigation potential seems to be far from complete compared with the range of performance variation due to human factors issues.
- Ultimately, to be useful, enhancement of SA should take the form of displays and systems that provide synthesized information rather than simply additional raw data for the end-user (i.e. Warfighter) to parse and integrate themselves.
- To provide useful informational displays requires detailed study of the impact of cognitive and perceptual constraints on the expected objective performance goals with the technologies being developed.

Thank you for your time and attention

dcs corp
Jason S. Metcalfe, PhD
Systems Engineer
Intelligent Systems Department
571-227-6272
jmetcalfe@dcscorp.com
www.dcscorp.com